Western Washington Land Cover Change Analysis

Final Report

Western Washington
Prepared for:

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Washington State - Department of Ecology

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1 PROJECT OVERVIEW

Description

The purpose of this project was to provide land cover data for Western Washington for a 1991 time frame and a comprehensive analysis of change in land cover, impervious surface, and forest canopy for all of Western Washington between 1991 and 2001. Classifying land cover for 1991 will contribute to land cover data recently classified under the NOAA Coastal Change Analysis Program (C-CAP) for 1996 and 2001. The primary dates included in the C-CAP analysis were 1996 and 2001, but image dates for the study area ranged from October 16, 1999 to February 26, 2002 for the 2001 data set and from September 18, 1995 to August 21, 1996 for the 1996 data set. For simplicity, these maps will be referred by a single date 1996 and 2001 in this document. Similarly the data that is being developed for this project will be referred to as 1991. The data for the 1991 data set range from July 7, 1991 to September 23, 1991. The analysis of change in impervious cover use of the C-CAP/USGS impervious data, while the analysis of change in forest cover was taken from the C-CAP land cover classification

The land cover change in impervious and canopy data were summarized by 2 sets of watershed basins. The first set of basins was developed from WAU and county watershed data and city of Seattle storm water basins. The second data set are the NPDES jurisdictions. The land cover data will be used by the storm water unit to assess relationships between landscape patterns, storm water program implementations, and ecological conditions in streams. Other state and local planners and resource managers can also use the information.

Study Area:

The geographic extent of the land cover analysis is identical to the study area for the 1996 and 2001 NOAA C-CAP land cover mapping and change analysis study area in Western Washington (Figure 1). The study area is bounded by the Cascade mountain range to the east, the Pacific Ocean to the west, the Canadian border to the north, and the Oregon border to the south.

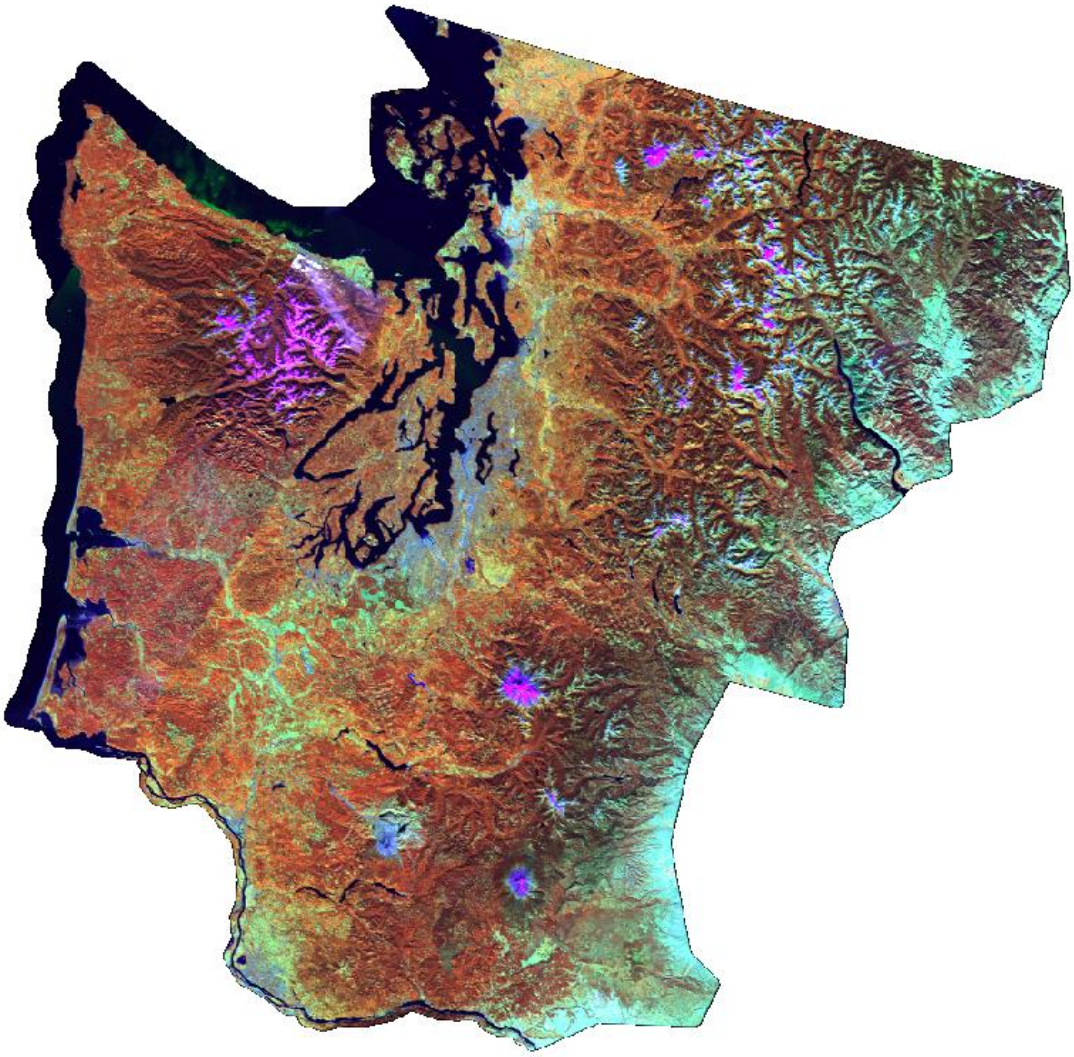


Figure 1: The 1996 and 2001 NOAA C-CAP land cover mapping and change analysis study area in Western Washington. This is same study area for this project.

Documentation

All GIS data products conform to the Washington State Geographic Information Technology Standards for Horizontal Datum and Coordinate System, and the Geographic Information Technology Standard for Metadata. The coordinate system and parameters used are listed below.

Coordinate System:
Lambert_Conformal_Conic
False_Easting: 1640416.666667
False_Northing: 0.000000
Central_Meridian: -120.500000

Standard_Parallel_1: 45.833333
Standard_Parallel_2: 47.333333
Latitude_Of_Origin: 45.333333
GCS_North_American_1983_HARN
Datum: D_North_American_1983_HARN
Prime Meridian: 0

Specifications

Sanborn purchased 1991 Landsat TM 5 data to complete the change detection from 1991 to 1996. Areas that had changed between the two time periods were classified into the appropriate land cover class. Land cover from areas that did not change was taken from the NOAA C-CAP 1996 land cover map. From/to change maps were made from the 1991 and 1996 maps, and from the 1991 and 2001 maps. From/to change maps were made from the 1996 and 2001 maps by the NOAA C-CAP program. Changes in land cover and in particular imperviousness and canopy were summarized by watershed and NPDES jurisdictions polygons. These polygon data sets were attributed with the change information. Assumptions for the analysis are listed below.

1. Land cover classification and change analysis is based on Landsat TM 30M imagery.
2. Land cover classification and change analysis used use the 2001 C-CAP land cover classification scheme and definitions (Appendices B and C) with one minor change. Three impervious classes (High Intensity Developed (100-80% Impervious, Medium Intensity Developed (79 – 50% Impervious), Low Intensity Developed (49 – 20% Impervious)) were defined instead of two (High Intensity Developed (100-80% Impervious), Low Intensity Developed (79 – 35% Impervious)).
3. The definition of forest cover from the 2001 and 1996 C-CAP maps was used. This definition stated that woody vegetation greater than 6 meters tall and with greater than or equal to 40% canopy cover is considered to be tree vegetation.
4. Changes from pervious surfaces to impervious surfaces were captured in the change analysis. Changes from impervious to pervious surfaces are assumed to be rare and were not mapped.

2 DETAILED WORK PERFORMED

Summary of Tasks Completed

2.1.1 Stream Basin Delineation

Sanborn acquired the statewide Watershed Administrative Unit (WAU) boundaries and more detailed information for Snohomish, King, Pierce, Clark, Kitsap and Thurston counties, and for the city of Seattle. The city of Tacoma did not have a more detailed data set. The collected data sets were merged into one file. Where more detailed data existed (counties and city), it was super imposed on the WAU data.

The adjoining county data was merged together first. Most of the county data had been delineated with consideration for the adjacent counties, so edge matching was simple in most areas. Once the county data was joined together, it was merged with the WAU basins. In general, the county data just replaced the basins in the WAU data. The county and WAU data also meshed together well. Even so, there were some issues that arose in joining both the counties together and the county to the WAU data. Issues were resolved with discussions with the Washington Department of Ecology. Described below are examples of the problems encountered and how they were resolved.

Decision 1: Study area extent

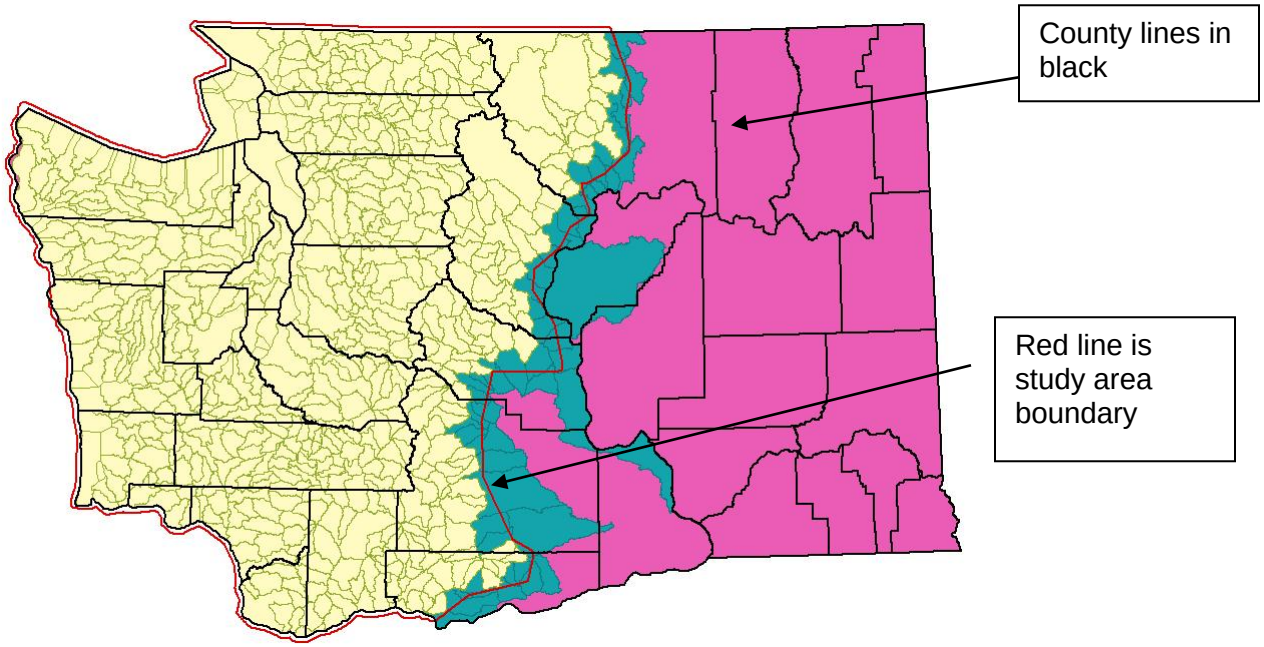


Figure 2: Washington state WAU polygons in yellow are entirely contained in the study area. Polygons in turquoise are partly contained within the study areas. Magenta areas represent the portion of Washington State that was not part of the study area.

Only WAU polygons that were entirely contained in the study area (polygons in yellow) were retained for the final analysis. The polygons that were partially within the study area would have only partial land cover, impervious, and canopy data so the summary values for the watershed polygons would not be accurate. Land cover and land cover change was mapped to the study area boundary though (red line).

Decision 2: Gaps between counties

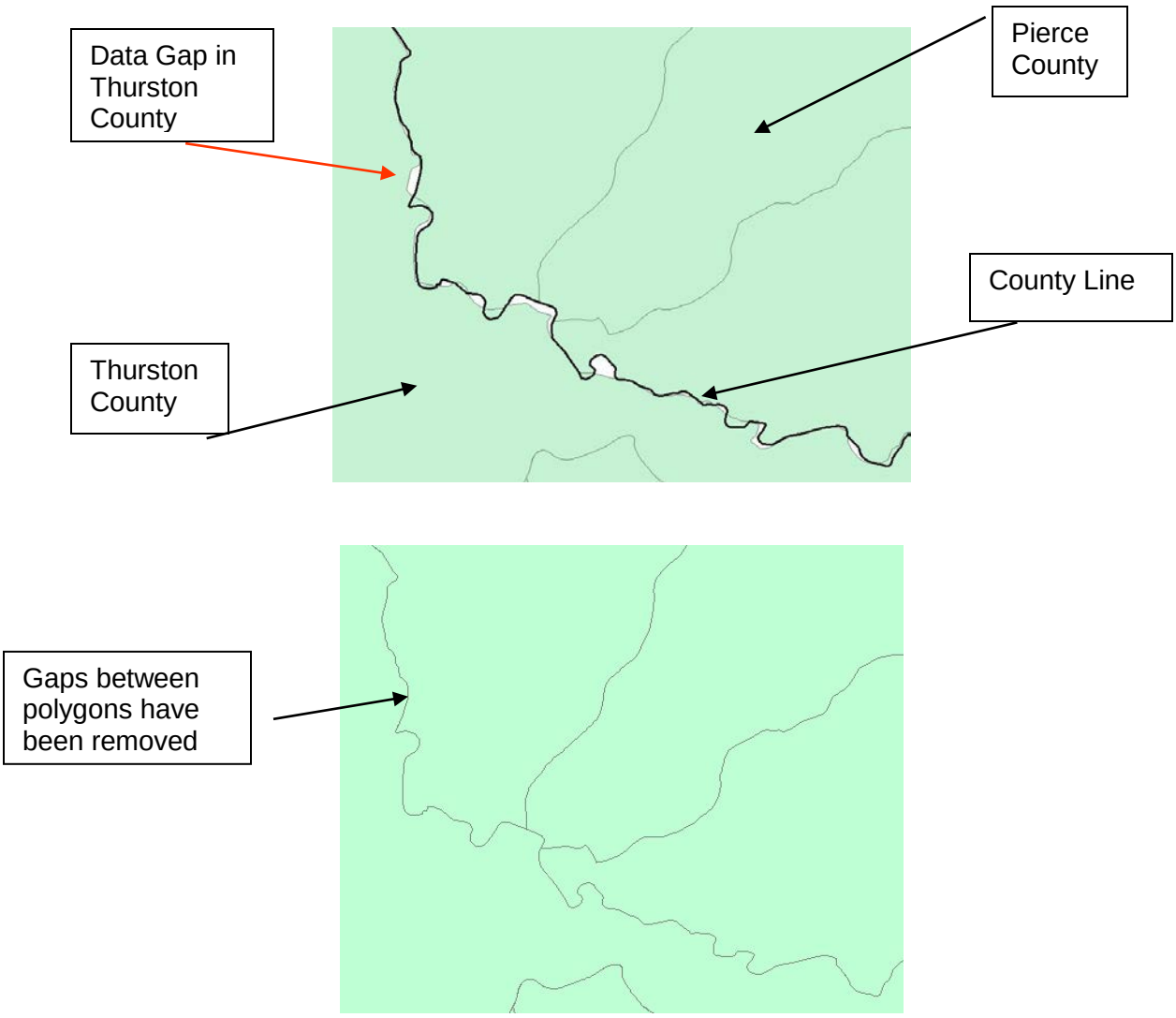
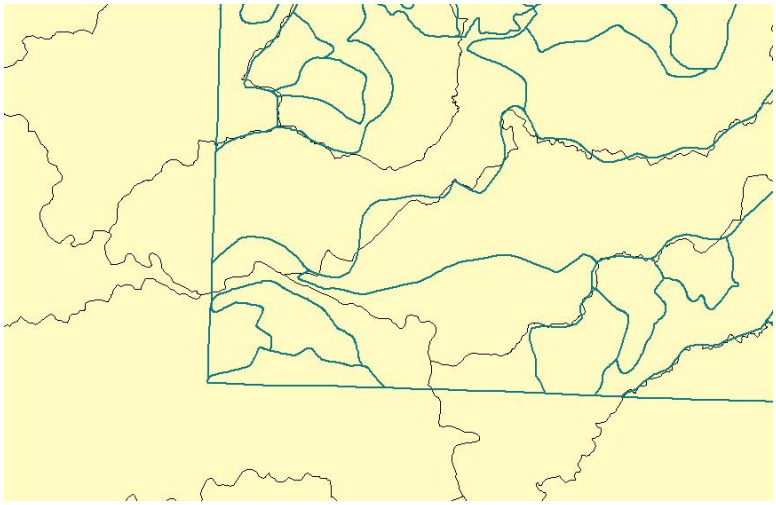


Figure 3: Gaps between county boundaries (top) and after they have been eliminated (bottom).

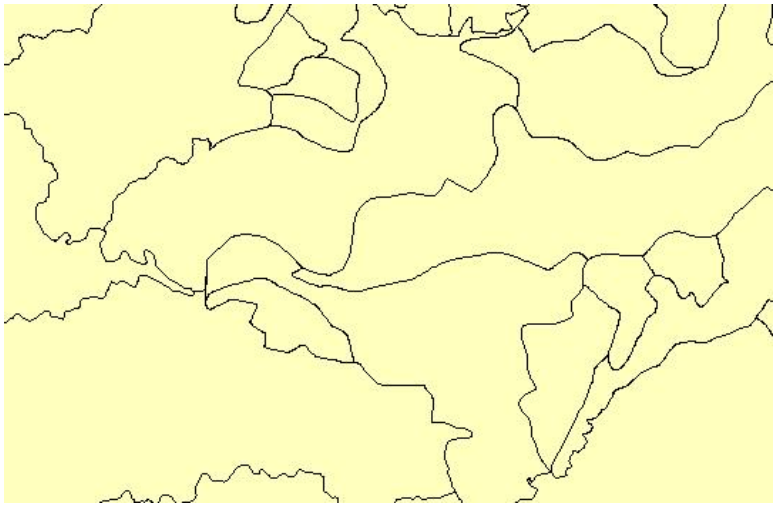
In some cases, the county delineated boundaries did not match and there were gaps in the watershed coverage. These gaps were eliminated so that the polygons met at the county boundary.

Decisions 3: Combining WAU and County data at county boundaries.



Before Merge

Black lines = WAU
Turquoise lines = county data



After Merge

Black lines show the final data set after the 2 files were joined.

Figure 4: Top image shows the WAU and County lines before the merge. The bottom image shows the watershed boundaries after they were merged.

In some cases, the county watershed delineations ended at the county boundary. This made the watershed boundaries very artificial. When possible, these partial county watersheds were extended outside the county boundary by using digital elevation models (DEMs) and aerial photographs to delineate the boundary along topographic breaks. Others partial watersheds were deleted when it would require a large area to be delineated outside the county. In these areas the WAU watershed lines were preserved.

Decision 4: WAU polygons show more detail in the eastern portion of the county data

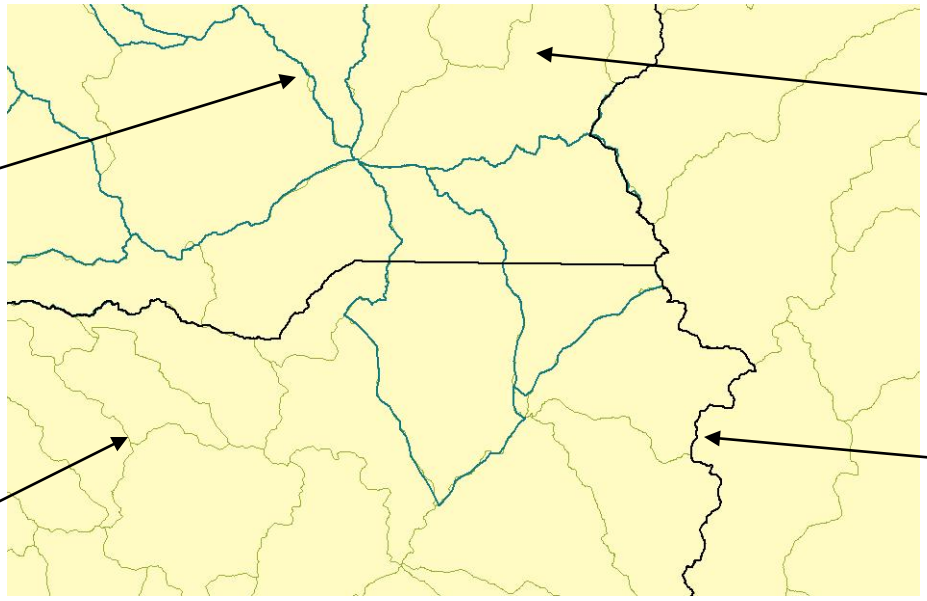


Figure 5: Comparison of the WAU and County watersheds in the Eastern portion of Pierce County.

The WAU watershed delineation was kept when they were more detailed than the county data. This occurred in the Eastern portion of the counties where the population density is low and the county delineated large basins. Also, if county watershed delineations went beyond the county line, they were retained.

After the county data was merged with the WAU data, the city of Seattle data was merged with the County/WAU data set. This was a little more difficult because the city designates combined sewer overflow areas which do not follow topography as do the other data sets. Because of this, the boundaries were not similar at all. The city of Seattle polygons were superimposed on the WAU/county combined data set (Figure 6). Portions of a basin that fell within a city of Seattle polygon were assigned the city CSO attributes. The remaining portion of the WAU/county polygon retained the original WAU/county designation and attributes. An attribute was added to the database named CSO and each polygon was labeled with one of 4 labels (Figure 7),

1. No = Polygon all or partially in the city of Seattle and **not in** the combined sewer overflow district.
2. Yes = Polygon all or partially in the city of Seattle and **is in** the combined sewer overflow district.
3. Non-Seattle = Polygon not in the city of Seattle
4. Water = Polygon is completely water and may or may not be in the city of Seattle

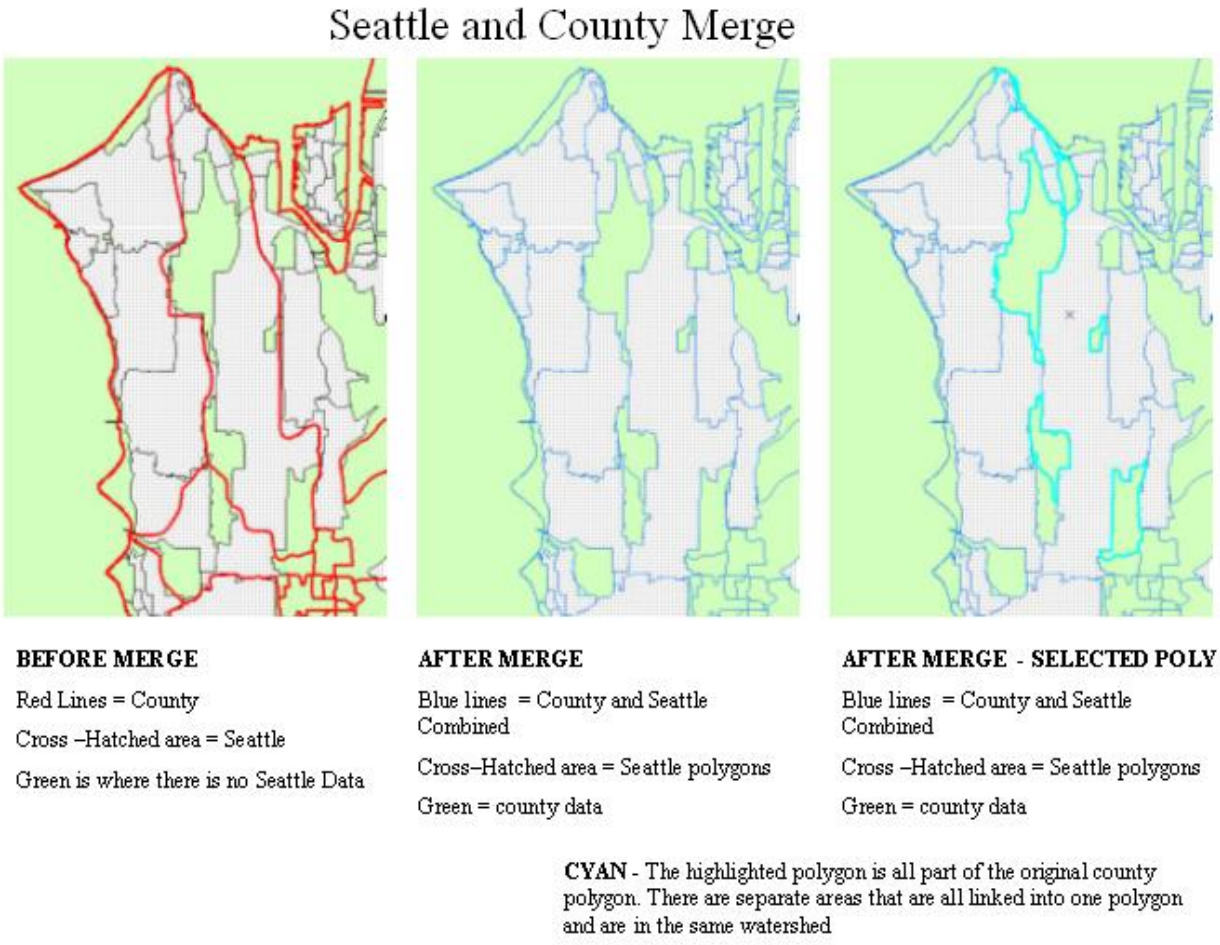


Figure 6: Merging Seattle city basins with the WAU/county combined file

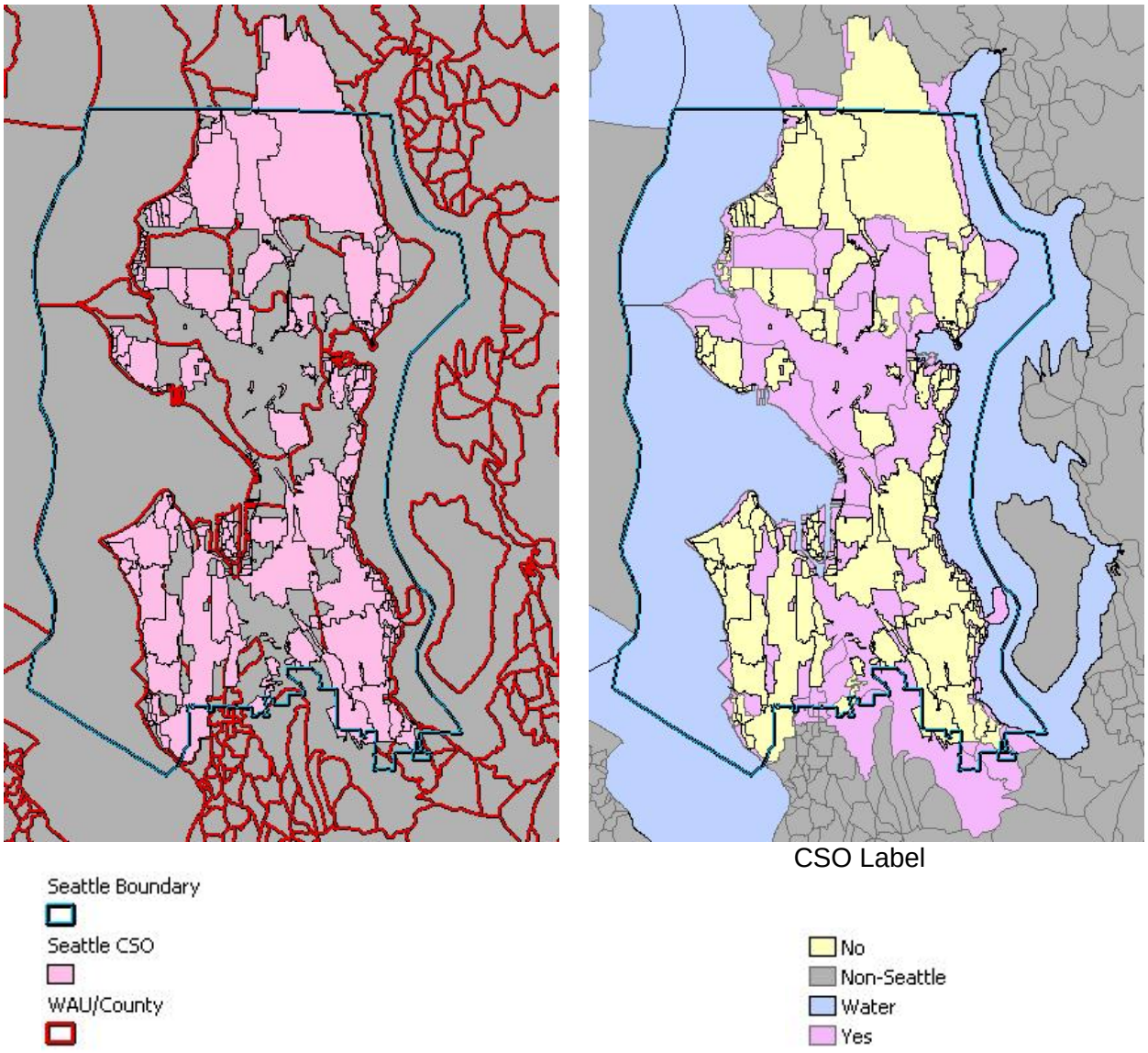


Figure 7: City of Seattle combined sewer overflow polygons (left) and after the merge (right). The polygons on the right are labeled as to whether they are in the combined sewer overflow areas of Seattle or not.

2.1.2 Adjusting 2001 and 1996 NOAA C-CAP Classification

NOAA's C-CAP classification for Washington State contains 21 classes (values 2 – 22) and only 2 impervious classes, High Intensity Developed (100 – 80% Impervious) and Low Intensity Developed (79 – 35% Impervious). The Washington Department of Ecology (DOE) was interested in mapping imperviousness down to 20% impervious. Since the developed classes in the NOAA C-CAP classification were derived from a

continuous value percent impervious data set developed by the USGS, we were able to modify the impervious classes for the DOE.

The first adjustment was to retrofit the 2001 and 1996 land cover maps with the continuous impervious values. The impervious data set was reviewed for errors against the TM data. Minor adjustments were made to remove non-impervious areas included in the data set. Impervious values were then imbedded on top of the 2001 Land cover classification (Figure 8). The new classification has values from 20 – 122 (Appendix D). The 2001 and 1996 images were reviewed to ensure that all changes in impervious areas were captured. Areas that were not impervious in 1996 (i.e. not developed) were removed from the impervious data set. This adjusted impervious data set was then used to create the updated 1996 land cover with values from 20 – 122 (Figure 9).

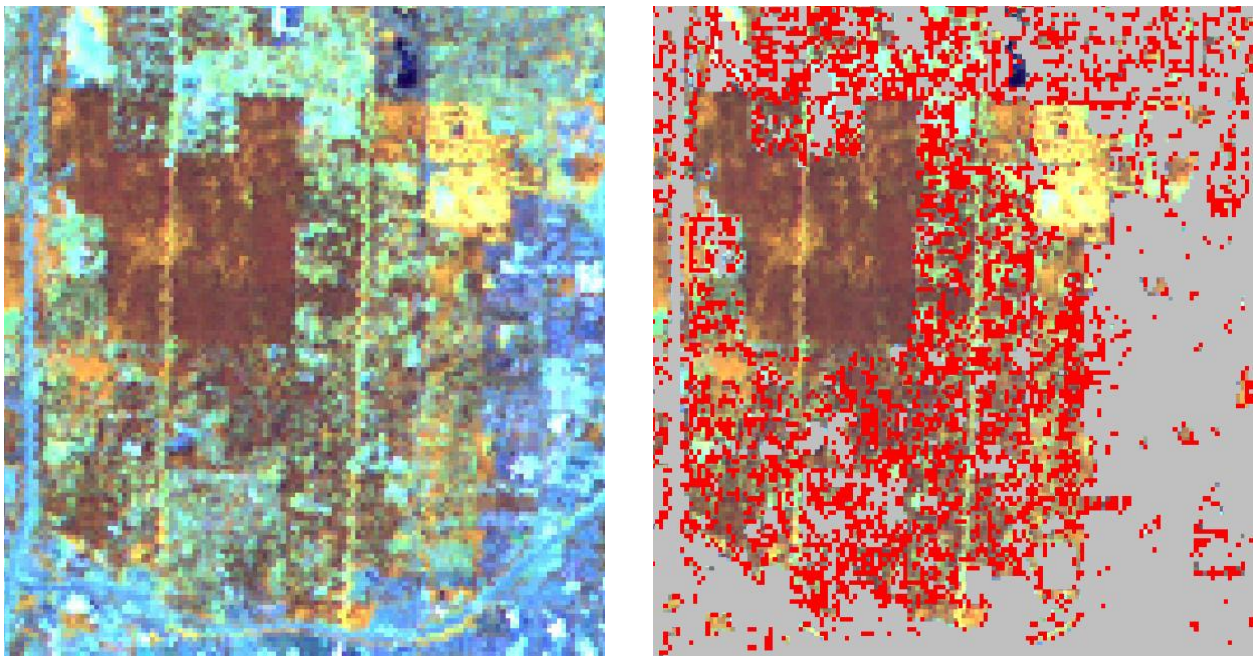


Figure 8: 2001 Landsat TM image (Bands 3, 4, 5) (left) and the same image with the impervious classification on top. Grey in the right image represents the original NOAA C-CAP classification where impervious values were mapped from 35 – 100% impervious. The red values represent impervious values from 20 – 34%. These areas were added to the classification.

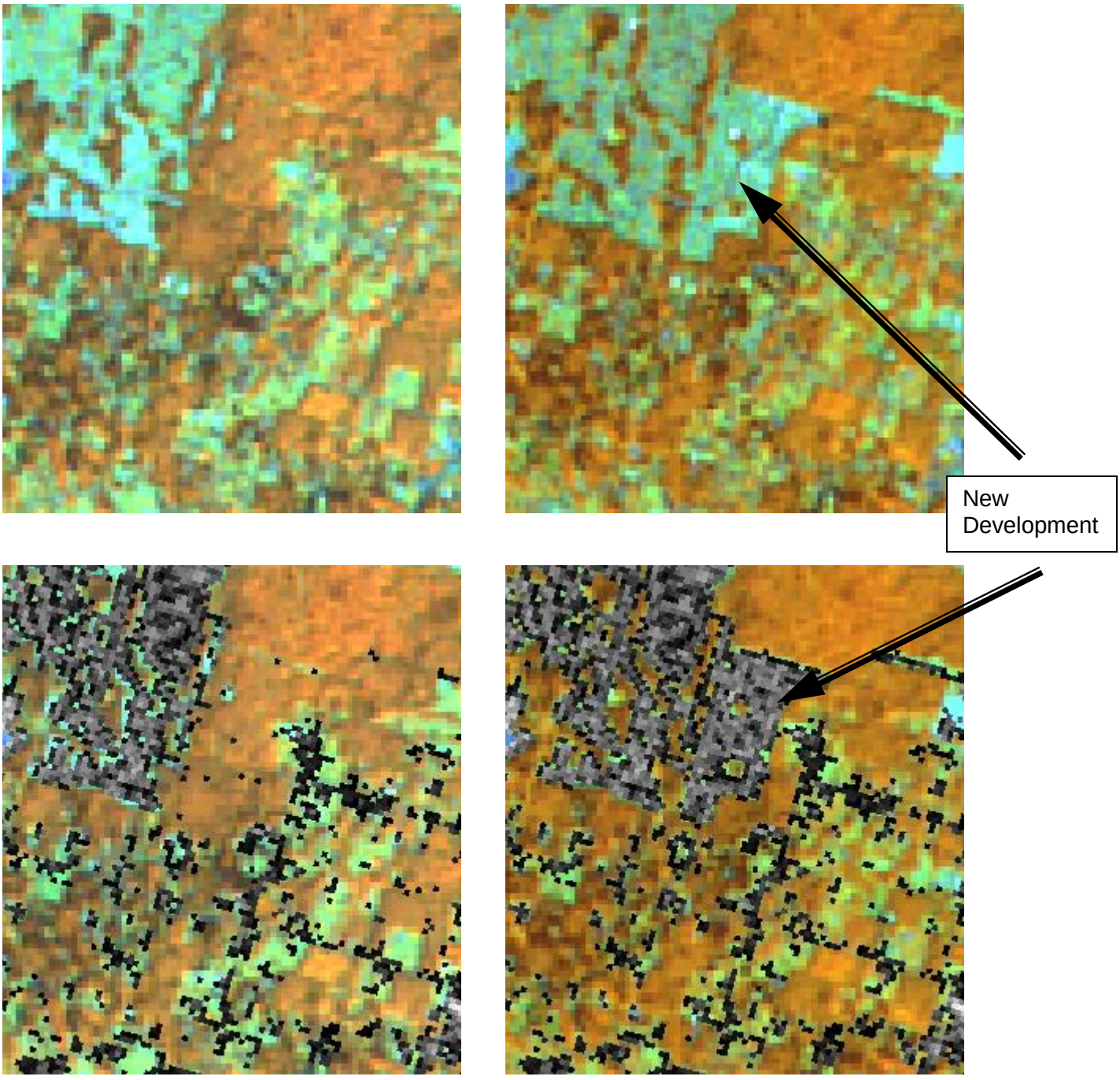


Figure 9: Landsat TM 1996 (Top Left) and 20001 (Top Right) images. Vegetation is in orange and yellows; Urban areas are blues. Bottom row shows the impervious classification on top of the images. Low to high percent impervious values are from black to white. The TM data are displayed in bands 4, 5, 3.

2.1.3 Change Detection 1991 - 1996

Landsat TM 5 data from 1991 were purchased and used to identify areas that have changed between 1991 and 1996. Areas that are identified as having changed were classified into the

DOE amended version of the NOAA C-CAP land cover classes (Appendix D). The 1996 C-CAP land cover data was used to provide a classification for the areas that did not change between the two time periods. The same methods had been used to create the NOAA C-CAP change detection from 1996 to 2001.

The first step in identifying areas that have changed was to spatially co-register the 1991 imagery to the 1996 imagery. Once the imagery was spatially co-registered, change detection was completed by calculating a difference image between 1991 and 1996. This step was completed on a scene-by-scene basis. The difference image highlights areas that show re-growth (re- vegetated clearcuts) from 1991 to 1996 and loss of vegetation (forest harvest and development) from 1991 to 1996.

Once the change areas were identified, the 1991 imagery was used to classify these areas into land cover classes. After the changed areas in the 1991 image were classified, a model was run to create a wall-to-wall map for 1991. In areas that changed, the 1991 classification was used and in areas that did not change, the 1996 map will be used to fill in these areas.

2.1.4 Creating Change Maps

Changes in land cover between 1991 and 1996, and 1991 and 2001were calculated from the 1991 land cover map with the 1996 and 2001 NOAA C-CAP maps. Because of the complexity of the change maps, the impervious values were recoded to 3 values before the maps were created. The output files have 484 classes representing all combinations of the 22 classes in each map (See Appendix D for the list of classes). For example, Class 163 would be mixed forest in 1991 and Scrub/Shrub in 1996. This area would likely be a clearcut in 1996. The classes in the input land cover maps were as follows,

1. 100 – 80% Impervious
2. 79 – 50% Impervious
3. 20 – 49% Impervious
4. Cultivated
5. Grassland
6. Deciduous Forest
7. Coniferous Forest
8. Mixed Forest
9. Scrub/Shrub
10. Palustrine Forested Wetland
11. Palustrine Scrub/Shrub Wetland
12. Palustrine Emergent Wetland
13. Estuarine Forested Wetland
14. Estuarine Scrub/Shrub Wetland
15. Estuarine Emergent Wetland
16. Bare Land
17. Unconsolidated Shore
18. Water
19. Palustrine Aquatic Bed
20. Estuarine Aquatic Bed
21. Tundra
22. Snow/Ice

The change map for 1996 to 2001 was re-created because of the additional impervious class.

2.1.5 Impervious Surface Change

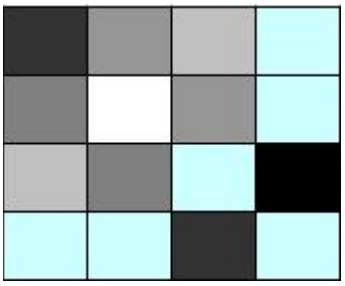
Percent impervious surface values were already mapped for 2001 for NOAA C-CAP/USGS Land cover programs. Percent impervious values for 1996 and 1991 were mapped by assuming that if there has been no change, the percent impervious will be the same as 2001. If there has been change, the land cover class will be mapped based on the Landsat TM satellite imagery. Areas of change in impervious surfaces were mapped for 1991 during the land cover change analysis. Impervious change areas and their classification had already been completed for 1996 as part of the NOAA C-CAP project, but were reviewed because the threshold percent impervious for this project was lowered to 20%.

Change in impervious surface was calculated for all of Western Washington, by stream basin, and by NPDES Phase 1 jurisdictions for each time period. These values are provided as attributes of the basin and NPDES GIS polygons. The percent impervious surface by basin equals the mean percent impervious surface value of all the pixels in the basin (Figure 10). In this example we would sum all 16 cell values and divide by the number of cells.

$$(20 + 79 + 84 + 0 + 67 + 93 + 79 + 0 + 84 + 67 + 0 + 20 + 0 + 0 + 20 + 0)/ 16 =$$

$$613/16 = 38$$

This basin is 38 percent impervious.



20	79	84	0
67	93	79	0
84	67	0	20
0	0	20	0

Black to White = percent impervious values from 20 – 100%

Blue = Percent Impervious values 0 - 19%. These are treated as 0 values

Figure 10: The impervious pixels in our sample watershed. On the left shows the raster data with each cell representing a percent impervious value. The right side shows the numerical values for percent impervious.

The percentage of impervious surfaces in a basin in 1991 and 1996 will be approximately equal to the percentage of impervious surfaces in that basin in 2001 minus the area of the pixels that are classified as pervious in 1991 and 1996, respectively. This approach assumes that it is very unlikely land will change from impervious to pervious over time, or that changes in the percentage of impervious surfaces within individual pixels will be significant.

2.1.6 Forest Canopy Change

Forest cover had already been mapped for 2001 and 1996 in the NOAA C-CAP data. Forest cover was mapped for 1991 during the land cover change mapping. Change in forest cover was calculated for all of Western Washington, by stream basin, and by NPDES Phase 1 jurisdictions for each time period. Forest cover is defined as those areas mapped into a forest class in the 2001, 1996, and 1991 C-CAP land cover classification and include the Deciduous, Mixed, Evergreen, and Palustrine Forest classes. Forest in these maps is defined as woody vegetation greater than 6 meters tall and having greater than or equal to 40% canopy cover. Unlike the impervious data set, the forest canopy data set was binary – If the area was labeled as forest in the classification, then it has 100% canopy or if it is not labeled as forest in the classification then it has 0% canopy. The percent canopy cover will be calculated using these values. Shown below is an example of a polygon made up of 10 cells.

Example Basin contains 30 pixels:

10 pixels labeled as forest = 10 * 100 = 1000
20 pixels labeled as non-forest = 20 * 0 = 0

1000 + 0 = (1000/30 pixels) = 33.3 percent forest cover

3 Making Corrections to the Data Sets

Overview

The current data set is based on three dates of imagery at a 30 meter resolution and cover Western Washington and the Eastern slope of the Cascade Mountains. While every effort has been made to ensure the accuracy of the data, there will be times when local knowledge of a specific area will be more accurate. In this case, the data can be updated to reflect the local knowledge. Updating the data is a two -step process. The first step is to update the raster data set. Once this is complete, the polygon information for that area will also need to be updated.

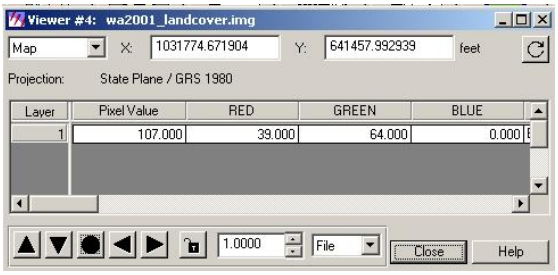
Updating the Classification

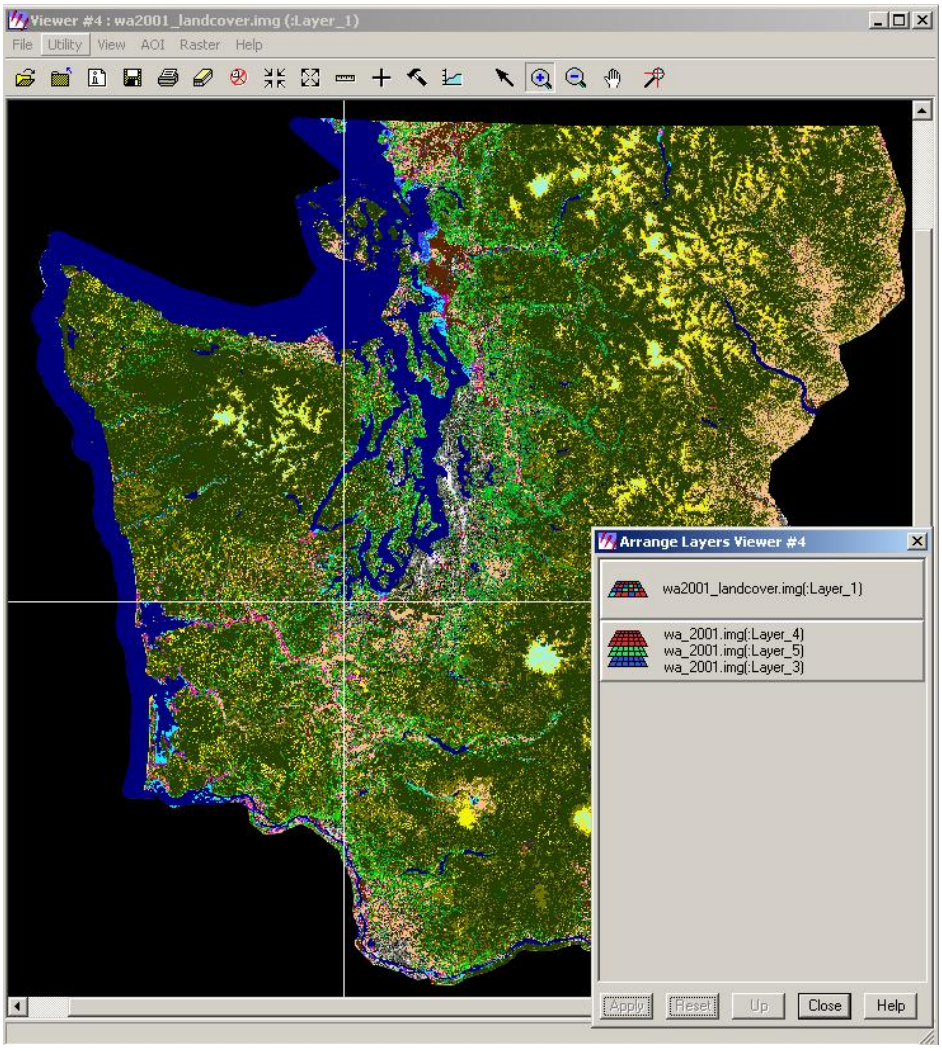
To update the classification (raster data set), one needs to edit the value of the pixels. While there are a number of programs that can do this, this example will be using ERDAS Imagine.

Example: Update an area in the 2001 land cover map that was labeled as impervious but is really a gravel quarry and would be better labeled as bare land and not impervious.

1. Load the 2001 image for reference and 2001 land cover classification with continuous impervious values for editing into the viewer. Have the 2001 land cover be the top file.

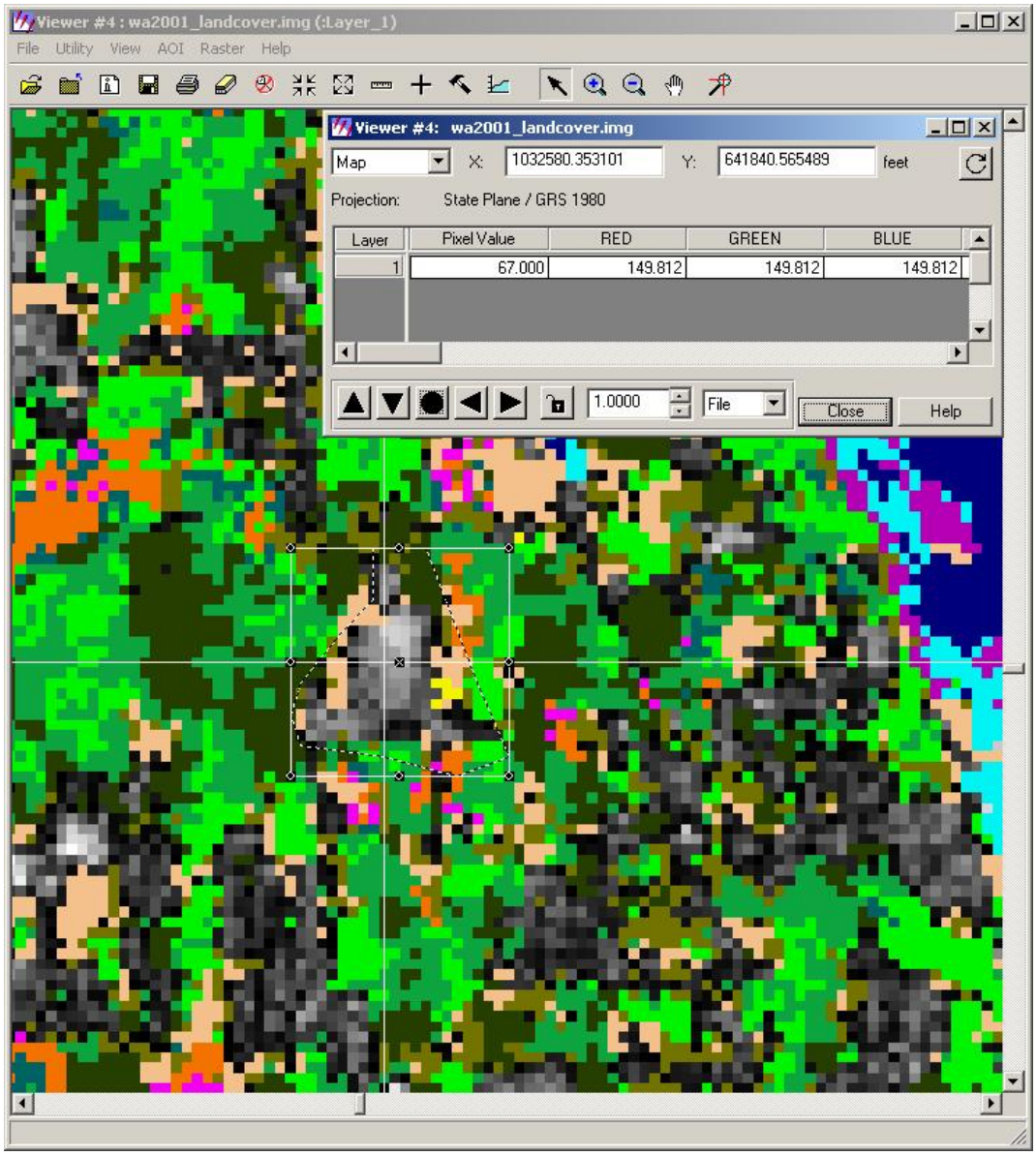
2. Locate the area to edit using local knowledge or a geographic coordinate.





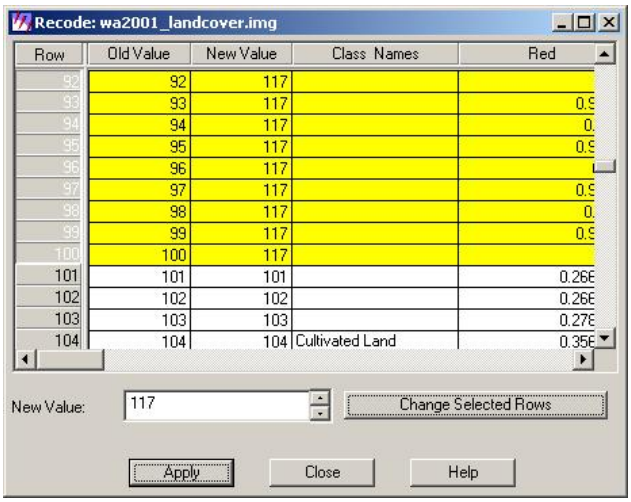
3. Bring up the AOI Tools.

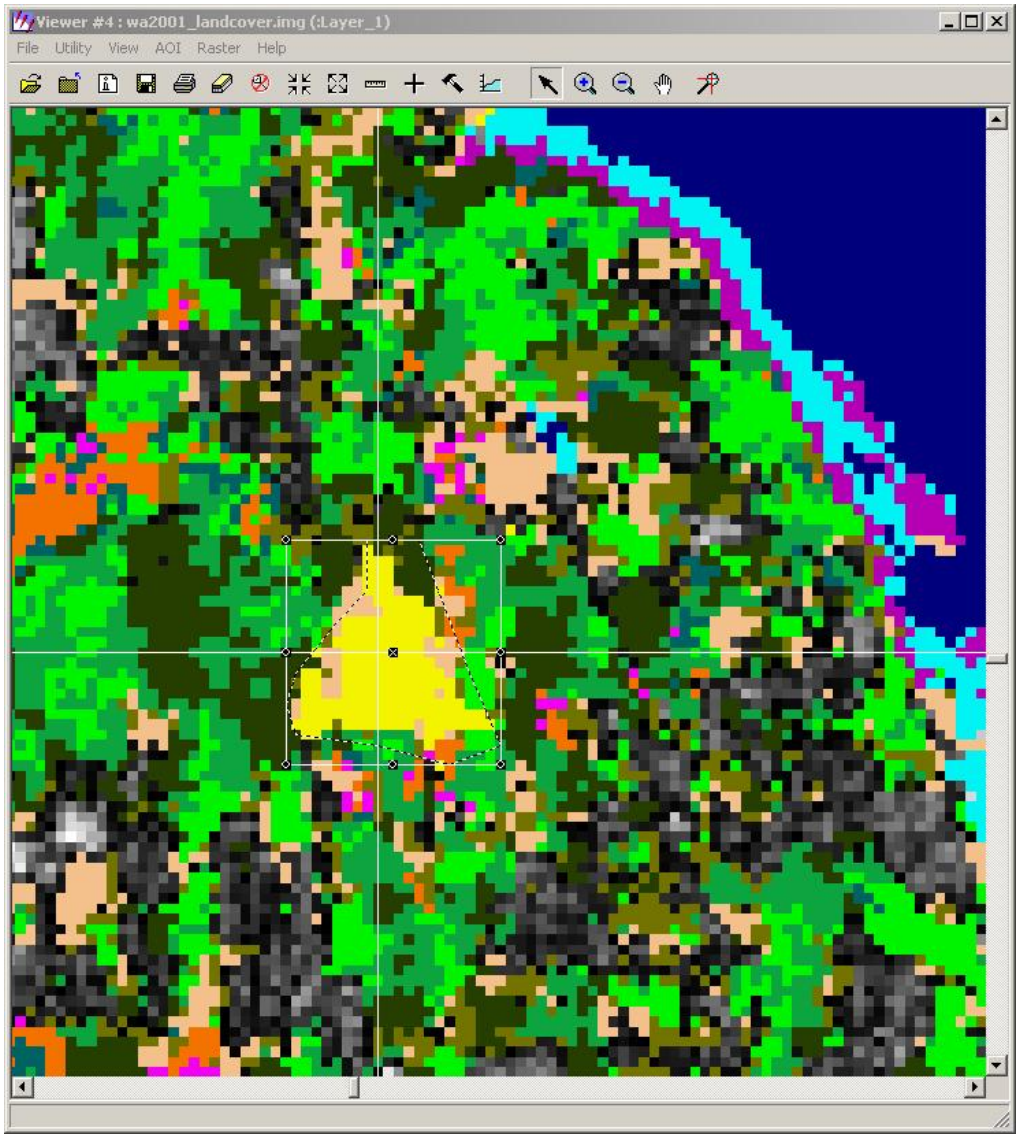
4. Draw a polygon that delineates the area that needs to be changed.



5. Bring up the cursor tool and determine the values of the pixels that need to be changed.

6. Bring up the Raster Recode dialogue. Enter in the new value to be given to the pixels. In this case, we are changing all impervious values (20 – 100) to the bare land category (117). Then hit apply. Continue drawing polygons and recoding areas until you have edited all the areas that need to be adjusted.


Recode: wa2001_landcover.img
Row
Old Value
New Value
Class Names
Red
92 92 117
93 93 117
94 94 117
95 95 117
96 96 117
97 97 117
98 98 117
99 99 117
100 100 117
101 101 101 0.266
102 102 102 0.266
103 103 103 0.278
104 104 104 Cultivated Land 0.356
New Value:
117
Change Selected Rows
Apply
Close
Help


Viewer #4 : wa2001_landcover.img (:Layer_1)
File Utility View AOI Raster Help

7. Save the File and remove it from the viewer. This may take some time as the program will recalculate the file statistics.

8. The 2001 Land cover map with continuous impervious values is the basis for all other products for 2001. The other 2001 products will need to be updated by recoding the values to create the other products. Use the **Recode** function in ERDAS Imagine to create the other maps.

   Impervious file

   Recode values 104 -122 to 0. This will retain the impervious values from 20 - 100.

   Canopy file

   Recode values 106, 107, 108 and 110 to 1 and recode the remaining values to 0.

   Land cover with 3 Developed Categories

Recode values	20 – 49	to 1
	50 – 79	to 2
	80 – 100	to 3
	104	to 4
	105	to 5
	106	to 6
	.	
	.	
	.	
	122	to 22

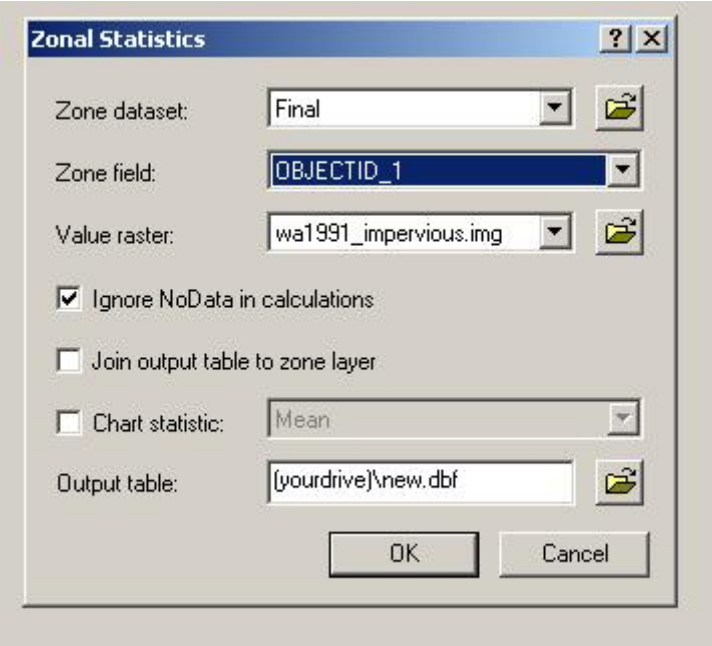
9. The files area now updated and the polygon information can be updated.

Updating the Polygon Attributes

To update the polygon attributes to reflect the changes to the raster data, identify the polygons that need updating and the attributes that will be affected. For example, if edits were made to the 1991 impervious data, this would affect the percent impervious for 1991 and the difference in percent impervious between 2001 and 1991 and 1996 and 1991. The percent impervious for 2001 requires some spatial analysis, while the differences in impervious values are just differences calculated from table values.

Example:
You find a polygon that needs to be re-run. As an example, you want to change a polygon's attribute data for 1991 impervious.

1. Open ARCMAP (assuming ArcGIS 9.0)
2. Add final.shp layer
3. select stream basin to edit
4. Use spatial analysis- and run zonal statistics on that polygon (It should look like this depending upon what image you are editing)



5. After the .dbf comes up for that polygon scroll to the "mean." That will be your new number to put into your shape file. The number will be a decimal, so you simply multiply this by 100 to get your percentage. (Example if it is .22, then that means you enter a 22 in your final.shp file.)
6. You can edit your shapefile if you start an editing session. Find the polygon number in the Attribute table and enter the new value for ***Imp_1991***. Remember to save your work periodically so that you have a back up in case you make any errors. It is always good to save an original and practice it a few times before you make any final edits.

7. Once you have updated the 1991 impervious value, the difference values will need to be updated too. High late the rows (= basins) that you want to update. Select ***the ImpCh01_91*** difference column and right click on the column heading and select the calculate option. This opens up a dialogue box that you can enter a formula to calculate the new value (see below). The ***ImpCh96_91*** will also have to be updated in the same way.

   Imp_2001 – Imp_1991

8. The Phase 1 NPDES jurisdiction Polygons will need to be updated in the same way.

APPENDIX A: Deliverables

All GIS data products provided conform to the Washington State Geographic Information Technology Standards for Horizontal Datum and Coordinate System, and the Geographic Information Technology Standard for Metadata

1. 1991 land cover classification for Western Washington on CD in ERDAS *.img format.
2. Copy of NOAA C-CAP Washington State land cover classification data for 1996 and 2001 on CD in ERDAS *.img format. These files have been updated to include the additional range in impervious values. All three files have two versions, one with continuous impervious values from 20 – 100% and the second where the impervious values are categorized into three classes High (100- 80%), Medium (79-50%) and Low (49-20) Intensity Developed
3. Digital data of continuous impervious surfaces for each of the three time periods in ERDAS *.img format.
4. Digital data of forest canopy for each of the three time periods in ERDAS *.img format.
5. Spread sheet showing impervious surface and forest canopy change analysis for Western Washington, all stream basins and the Phase 1 NPDES jurisdictions.
6. The Updated version of stream basin polygon GIS layer combines the WADNR and local government stream basin polygons and contains the following additional attributes with the table attribute name given in bold italics:
   - Total Percent Impervious 2001 = ***Imp_2001***
   - Total Percent Impervious 1996 = ***Imp_1996***
   - Total Percent Impervious 1991 = ***Imp_1991***
   - Change In Total Percent Impervious 1991-1996 = ***ImpCh96_91***
   - Change In Total Percent Impervious 1996-2001 = ***ImpCh01_96***
   - Change In Total Percent Impervious 1991-2001 = ***ImpCh01_91***
   - Percent Canopy 2001 = ***Can01***
   - Percent Canopy 1996 = ***Can96***
   - Percent Canopy 1991 = ***Can91***
   - Change In Canopy 1991-1996 = ***CanCh91_96***
   - Change In Canopy 1996-2001 = ***CanCh96_01***
   - Change In Canopy 1991-2001 = ***CanCh91_01***
7. Updated version of NPDES Phase 1 Jurisdictions polygon GIS layer containing the following additional attributes:
   - Total Percent Impervious 2001 = ***Imp_2001***
   - Total Percent Impervious 1996 = ***Imp_1996***
   - Total Percent Impervious 1991 = ***Imp_1991***
   - Change In Total Percent Impervious 1991-1996 = ***ImpCh96_91***
   - Change In Total Percent Impervious 1996-2001 = ***ImpCh01_96***
   - Change In Total Percent Impervious 1991-2001 = ***ImpCh01_91***
   - Percent Canopy 2001 = ***Can01***
   - Percent Canopy 1996 = ***Can96***
   - Percent Canopy 1991 = ***Can91***
   - Change In Canopy 1991-1996 = ***CanCh91_96***
   - Change In Canopy 1996-2001 = ***CanCh96_01***
   - Change In Canopy 1991-2001 = ***CanCh91_01***

APPENDIX B: NOAA Original Classification Scheme

Class Number	Land Cover Category
0	Background
1	Unclassified (Cloud, Shadow, etc)
2	High Intensity Developed
3	Low Intensity Developed
4	Cultivated Land
5	Grassland
6	Deciduous Forest
7	Evergreen Forest
8	Mixed Forest
9	Scrub/Shrub
10	Palustrine Forested Wetland
11	Palustrine Scrub/Shrub Wetland
12	Palustrine Emergent Wetland (Persistent)
13	Estuarine Forested Wetland
14	Estuarine Scrub/Shrub Wetland
15	Estuarine Emergent Wetland
16	Unconsolidated Shore (Intertidal Beach Areas, Flats, Bars)
17	Bare Land
18	Water
19	Palustrine Aquatic Bed
20	Estuarine Aquatic Bed
21	Tundra
22	Snow/Ice

APPENDIX C: Decision Rules for NOAA C-CAP Amended Classes

If land area has > or = 30% open water then **Water (18)**

Else if land area > 50% snow/ice throughout the year then **Snow/Ice (22)**

Else if land area > 20% covered with areas characterized by impervious structures (e.g. Asphalt, concrete, buildings, etc.) then **Developed**

Developed

If land area > or = 80 % impervious then**, High Intensity Developed (1)**

If land area > or= 50% Impervious then, Medium Intensity Developed (2)

Else **Low Intensity Developed (3)**

Else if land area is characterized by herbaceous vegetation that has been planted or is intensely managed for the production of food, feed or fiber then **Cultivated Land (4)**

Else if > 50% tundra vegetation, then **Tundra (21)**

Else if land area > 50% covered with bare rock, gravel, sand, silt, clay or other earthen materials then

Bare Land

If characterized by inter-tidal, or intermittently flooded areas (mud flats), then **Unconsolidated Shore (16)**

Else **Bare Land (17)**

Else if land area is periodically flooded or covered with water and/or on hydric soils, then **Wetland**

Wetland

If salinity due to ocean-derived salts is below 0.5 percent then **Palustrine Wetland**

If > 50% of non-water ground cover is tree canopy > 6 m in height then **Palustrine Forested Wetland (10)**

Else if > 50% of non-water ground cover is woody then **Palustrine Scrub/Shrub Wetland (11)**

Else if > 50% plants growing and forming a continuous surface principally on or at the water surface then **Palustrine Aquatic Bed (19)**

Else **Palustrine Emergent Wetland (12)**

Else (salinity due to ocean-derived salts is above 0.5 percent) **Estuarine Wetland**

If > 50% of non-water ground cover is tree canopy > 6 m in height then **Estuarine Forested Wetland (13)**

Else if > 50% of non-water ground cover is woody then **Estuarine Scrub/Shrub Wetland (14)**

Else if > 50% plants growing and forming a continuous surface principally on or at the water surface then **Estuarine Aquatic Bed (20)**

Else **Estuarine Emergent Wetland (15)**

Else if woody vegetation $\geq$ 40%

Woody Vegetation

If tree canopy (woody vegetation) $\geq$ 67% deciduous then **Deciduous Forest (6)**

Else if tree canopy > or = 67% evergreen then **Evergreen Forest (7)**

Else **Mixed Forest (8)**

If tree canopy (woody vegetation) $\leq$ 6m Tall) then **Shrub/Scrub (9)**

Else Grassland (5)

APPENDIX D: Classification Scheme for Washington Department of Ecology Maps

Class Number	Land Cover Category
0	Background
20	20 Percent Impervious
21	21 Percent Impervious
22	22 Percent Impervious
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97	97 Percent Impervious
98	98Percent Impervious
99	99 Percent Impervious
100	100 Percent Impervious
104	Cultivated Land
105	Grassland
106	Deciduous Forest
107	Evergreen Forest
108	Mixed Forest
109	Scrub/Shrub
110	Palustrine Forested Wetland
111	Palustrine Scrub/Shrub Wetland
112	Palustrine Emergent Wetland (Persistent)
113	Estuarine Forested Wetland
114	Estuarine Scrub/Shrub Wetland
115	Estuarine Emergent Wetland
116	Unconsolidated Shore (Intertidal Beach Areas, Flats, Bars)
117	Bare Land
118	Water
119	Palustrine Aquatic Bed
120	Estuarine Aquatic Bed
121	Tundra
122	Snow/Ice